NUTRITIONALLY FORTIFIED CEREAL FOODS

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The fragile and precarious balance which exists between world food supply and demand was starkly emphasized in the statistics presented to the World Food Conference held in Rome in the autumn of 1974. The Executive Director of the World Food Council, John A. Hannah, stated recently that if present production patterns persist, within 10 years the annual deficit in food grains in the developing countries will reach close to 100 million tons annually; a level which Hannah described as "unmanageable either financially or physically".

Dr. Hannah stated: "In essence, this means raising food production in the developing world from 2.6 percent annually that has prevailed in the past, to at least 3.6 percent a year in the next 10 years. Hopefully, it will increase even faster in order to alleviate malnourishment which is the condition of over 430 million people, of whom almost half are children."

The subject of this paper is "Nutritionally fortified cereal foods". There is a very substantial body of literature on this subject, much of which is recorded by biochemists, nutritionists and cereal chemists. The scientific literature has been reviewed in several publications*. In this paper,

* J.H. Hulse, B.D. Fawcett, W.D. Daniels, Protein Supplements - World Production and Trade, Oilseed and Pulse Crops in Western Canada, 1975.

J.H. Hulse, The Protein Enrichment of Bread and Baked Products, New Protein Foods, Vol. 1A, 1974.

J.H. Hulse, E.M. Laing, Nutritive Value of Triticale Protein, 1974.

we propose to deal rather more with aspects of production, economics and trade than with science and technology.

In several countries, including Canada, it is obligatory to enrich commercially milled wheat flour with the vitamins thiamin, riboflavin and niacin, and with iron. In some countries the addition of calcium to "long extraction" wheat flours is also required. The addition of vitamins and minerals to cereal foods is technologically a simple procedure and will not be discussed in this paper.

Practically every known essential vitamin and mineral has been added to different cereal foods for different consumers. This is particularly true of infant and weaning foods, and calorie controlled compositions. In the time and space available, it is not possible to discuss comprehensively all of the nutritional implications of such fortified cereal combinations. The paper will therefore focus mainly upon the supplementation of cereals with protein and, in particular, the supplementation of cereals with proteins derived from legumes and oilseeds.

Production and Consumption of Cereals and Legumes

As can be seen from Table I, cereal grains, food legumes and nuts provide most of the calories and protein for most of the people of Africa, Asia, Latin America and the Near East. There is every indication that until the end of this century and beyond, the importance of cereals and legumes in the diet, particularly of the poorest people, will increase rather than decline. Though it might appear from a cursory examination of world production and population statistics (Table IX) that annual per capita cereal production is increasing at a faster rate than world population and that protein supplies are universally adequate (Tables IV and V) estimates of total regional production and population take little account of the wide variability in availability and distribution which exists among regions, among countries, among communities within a given country, among families within a community and even among members of the same family. Though the tentative forecast for grain harvest in many of the principal producing countries for this year are encouraging, there is certainly no cause for complacency in that world supplies of grains and legumes are at present at their lowest level for many years and it is common knowledge that serious food shortages exist in a number of developing regions.

Over the past decade, the greatest increase in both grain production and consumption has been found in the economically developed countries which feed most of their surplus grain to animals. For example, in the United States, of the 900 kilograms per person per year of cereal grains produced, only 50 kilograms per person is eaten directly by humans. The remaining 850 kilograms per person is used in the production of meat, meat by-products, dairy products, eggs and alcoholic beverages. By comparison, in India, almost all of the estimated 170 kilograms per capita of cereals produced per annum is eaten directly by human beings.

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Cereals in Human Diets

Cereals are important in human diets as a primary source of calories, of several important vitamins and minerals, and of protein. "Protein" is the name given to a class or organic substances which are made up of linked amino acids composed of nitrogen and other elements. Amino acids are the essential building materials of which all animals' tissues and organs are composed and maintained. Protein is essential to the growth and restoration of body tissue and is particularly important in the diets of young children, pregnant and lactating women, and to aid recovery after serious illness or injury. There is evidence to suggest that serious protein deficiency in early childhood can impede brain development and learning ability. Different proteins are composed of different combinations of amino acids. Some amino acids can be synthesized by living organisms from other sources of organic and inorganic nitrogen. The amino acids which can be synthesized vary among different higher animals. Amino acids, essential to the animals' diet which cannot be synthesized but must be ingested as such, are known as "essential" amino acids and must be provided in the food which is eaten. Human beings require at least 10 essential amino acids and when these 10 amino acids appear together in appropriate proportions in a single protein source, that source is described as an "ideal" or "perfect" source of protein.

Though the protein content of cereals varies widely, for example on a dry weight basis, the protein content of wheat from different sources has been reported to vary from 7% to 26%, almost all cereal proteins are deficient in the essential amino acid lysine. The nutritional value of a cereal grain can be therefore improved by the addition of synthetic lysine or by the addition of a food which is rich in lysine. One can list a great many protein foods of animal, vegetable and microbiological origin which are rich in lysine and which might be used to supplement cereals. However, for reasons already given, this paper will concentrate largely upon legume and oilseed proteins since these appear to represent the most promising source, particularly for developing countries. Table II presents a list of protein sources which, in addition to the legumes listed in Table VI, have been tested or suggested as supplements to improve the nutritional quality of cereal proteins.

Nutritional Complementarity of Cereals and Legumes

Food legumes are comparatively rich in lysine and therefore a combination of cereal protein and legume protein comes very close to providing an ideal source of dietary proteins for human beings. Tables IIIa and IIIb show the amino acid content of wheat, chick-pea and rice together with what might be described as "a perfect protein" as recommended by WHO. From Table IIIa it can be seen that the WHO recommended content of lysine is 340 mg/g of nitrogen. A typical wheat protein supplies only 179 whereas chick-pea provides 428 mg lysine per gram of nitrogen. An almost perfect mixture of wheat and chick-pea occurs when 67% of wheat is mixed with 33% of chick-pea. Column 3 shows the resulting amino acid content and what is called the Amino Acid Score which is expressed as a percentage of the WHO recommended level. It can be seen that wheat plus chick-pea provides more than 85% of all the amino acids required. Table IIIb shows that when rice and chick-pea are combined in the ratio of 75 to 25%, with the exception of methionine and cystine, the amino acid balance is almost perfect.

The nutritional complementarity of cereals and legumes is of extreme importance, particularly for the people of the less developed world. From Table IV it can be seen that whereas North Americans consume nearly 100 grams of protein per person per day, most developing nations, upon average, consume between 45 and 65 grams of protein per person per day. It must be emphasized that these statistics, as with all others quoted, are averages for total populations and that the poorest members of these populations will probably consume considerably less than the national or regional averages. Table V suggests that in 1970 there was more than enough protein but a deficiency of calories in terms of percentage requirement for most developing regions. However, once again, one must remember that these are gross averages and take no account of a lack of uniformity in distribution.

In order to achieve optimum nutritional complementarity, cereals and legumes need to be eaten in an approximate ratio of 65 of cereal to 35 of legume. According to FAO total production statistics, only in Latin America does the production ratio of cereal to legume approach the desirable 65 to 35 ratio. In Southeast Asia, the ratio is closer to 90 cereal to 10 legume.

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There is convincing evidence from South and Southeast Asia to suggest that over the past twenty years the per capita production of food legumes has declined significantly, chick-peas from 6 to 3, soy beans from 1.2 to 0.9, lentils from 0.6 to 0.4 kg. per person per year.

For the world as a whole between 1952 and 1972, the population increased by 40%, total food production by 61% and legume production by 49%. For the developing countries collectively, population increased by 53%, total food production by 62%, but food legumes by only 40%. In Asia and the Far East, the population increased 51%, total food by 65%, but legumes by only 21%.

Food Legumes

The botanical family Leguminosae, characterized by the fact that their seeds are contained in pods, is one of the largest families of flowering plants comprising nearly 700 genera and 18,000 species. Legumes which are eaten by humans are usually called food legumes or grain legumes and these may be partitioned into two sub-groups, the pulses and the oilseeds. The pulses are the dried edible seeds of cultivated legumes, whereas the oilseeds, as their name suggests, are sources of both edible oil and protein. Table VI lists the world's principle legumes, by botanical and common name, and gives their estimated level of production.

The food legumes are eaten in a wide variety of ways. The green seeds may be cooked as vegetables; they may be dried, parched or toasted; they may be ground into flour and cooked as such or mixed with cereal flours; they may be fermented or allowed to germinate; they may be modified chemically or microbiologically to produce bean curds and pastes. From soybean, groundnut and sesame, the oil may be extracted by pressing or by solvent extraction. In many countries the high protein residue following oil extraction is usually fed to animals, but recently processing methods have been developed whereby to extract high protein isolates from the oil-free meal for subsequent conversion to a variety of edible forms.

It is difficult to compare the cost of different sources of protein largely because of the highly variable cost of production among different countries and different economic systems. However, as a rough rule of thumb, one can say that the cost per kilogram of utilizable protein from meat or meat by-products is about 10 times the cost of a kilo of utilizable protein from an edible legume.

Production of Legumes

As stated above, world cereal production is increasing much more rapidly than the production of legumes, consequently the need to increase legume production on a worldwide basis and in particular in South and Southeast Asia must be regarded as a matter of serious concern. The importance of pulse crops as a group has declined over the past decade as the share of pulses in total world agricultural production fell from 2.3 to 1.9%. The seriousness of this trend in developing countries is illustrated by the fact that it was in developed countries that the greatest increase in production has occurred.

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In the more developed countries, pulse production rose substantially between 1948-52 and 1968-72 as a result of the 87% increase in total production, which was well ahead of the population growth of 22%. Despite a decline in the per capita production of many pulse crops such as dry beans, broad beans, chick-peas, lentils and other pulses, per capita production of dry peas, vetches and lupins increased rapidly enough to offset these trends and led to the overall growth in per capita production in the developed countries.

In general, the world production of pulse crops exceeded population growth only slightly from 1952 to 1972, with production increases falling below population growth in the less developed nations and rising much more rapidly than population in the more developed countries. Cowpea and dry bean production advanced most quickly in the less developed countries as a result of both higher yields and larger areas planted with these crops.

In Canada, pulse production has remained relatively unimportant until recently, when the supplies of plant protein became less plentiful. Even in 1972, pulse crops occupied only 0.4% of the total crop land in Canada, and contributed only 0.3% to the total crop production in Canada. Canadian pulse production increased by 15% from 1948-52 to 1968-72, which was far below the population growth of 55%.

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A number of factors affect legume production. First of these is "yield" which is the agronomist's term for the weight of edible seed produced per hectare or other unit area of land. Yields of pulse crops generally, and in particular those of tropical countries, have increased very slowly over the past two decades in comparison with the major cereals. With the exception of dry peas, whose yields over the past 20 years rose by 34%, the yield increase for pulses was less than 20%. In contrast, wheat yields increased by 52% and maize by 61%.

The second factor which affects total legume production is the area planted to legumes. On a worldwide basis, from 1948-52 to 1968-72, the cultivated area of a few pulse crops has increased. The acreage under cowpeas increased by 172%, and the total area planted with dry beans and dry peas rose by 50 and 34% respectively during this period. The area planted to other pulse crops remained stable or declined over the same period.

Oilseed Production

While pulse production has risen slowly from 1948-52 to 1968-72, the oilseeds have been produced in increasingly large numbers. The area planted with soybeans rose by 123% from 1948-52 to 1968-72 with production jumping almost 200% due to a 30% increase in yields. Although the production of other oilseed crops did not rise nearly as quickly as soybeans, the cultivation of groundnuts expanded by 60% while production rose by 77% as yields increased by 10%. Rapeseed was also a crop experiencing considerable growth as the planted area grew by 80% and production rose 100% assisted

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by a 25% yield increase. Sunflower acreage expanded by nearly 40%, yields increased by more than 100%, to give rise to an overall increase in production of close to 150%. Land planted to cottonseed grew by only 20% but production rose by 114% in the wake of a 100% yield increase. Sesame acreage increased by 20%, but total production did not rise significantly over the twenty year period as a result of a 6% decline in yields.

It is the opinion of the authors that much more attention needs to be given to increasing the production of oilseeds, particularly those, such as cottonseed, groundnuts, rape, safflower and sesame, which can be grown in many developing countries.

Apart from soybeans, and to a lesser extent groundnuts which are of importance in international trade largely for their oil content, oilseeds have been as badly neglected as pulses in terms of investment in their research and development. The oilseeds are particularly important in that they provide not only good quality protein but also those unsaturated fatty acids which are essential in the diets of all human beings.

Legumes have a number of agronomic advantages, the most important of which is that they are capable of fixing their own nitrogen. Certain soil microorganisms in association with the legume root nodules are able to reduce atmospheric nitrogen to ammonia which is absorbed and converted to protein within the legume.

Consequently, legumes are much less dependent upon chemical or organic fertilizers than are cereal grains and legumes tend to improve the soil conditions for other crops. A number of instances have been reported in which the intercropping of legumes and cereals led to an increased production of cereal grains and a total increase in productivity per unit area of land compared with either crop grown separately.

Legume and Oilseed Prices

As Table XII indicates, during the past three years legume and oilseed prices have been subject to extreme fluctuation. Until early 1972, prices had remained relatively steady for many years. During the latter months of 1973, prices rose as high as six times the earlier prices. In the dry beans group, navy beans, which formerly sold for $225 to $325 per metric ton were commanding prices of $900 by November 1973. White kidney beans, which previously were valued at $50 to $100 per metric ton, reached prices of $650 to $700 in late 1973 and red kidney beans doubled in price from $250 to $500 at the start of the 1974 trading season. Dry peas increased from the normal $150 to over $500 per metric ton. Similar price increases were recorded for other legumes and the oilseeds traded on the world markets. Although these prices receded substantially in late 1974 and in 1975, in many cases they still remain well above the earlier price levels as has been the case with most protein supplements in today's world markets.

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Trade in Legumes

World trade in pulses remains small in comparison with major commodities such as cereals. World trade in pulses in 1972 amounted to only 1.4% of the volume and 3.8% of the monetary value of world trade in cereals. Over the past decade, from 1963 to 1972, the volume of pulse trade has remained relatively stable, increasing only 20% with exports rising from 1.5 million metric tons to 1.8 million metric tons. In comparison, the world trade in cereals rose by 44% while soybean trade rose by 70% in the period from 1967 to 1972 alone.

Despite the fact that they exported only 4% of their production, the less developed countries were responsible for 51% of the world trade in pulses in 1972. The developed countries provided 35% of the total exports, with the centrally planned economies exporting the remainder. Of the more developed countries who purchased 67% of the 1972 imports, Europe was the primary importing area, buying 54% of the total 1972 world imports. Canada holds a minor position in the world pulse trade, exporting 1.4% and importing 0.5% of the total world imports during 1972. About 30% of Canada's pulse production is exported.

Between 1963 and 1972, world exports of oilseeds increased from 9.5 to 19.4 million metric tons. The more developed nations are the major exporters of oilseeds mainly because soybeans represent 71% of total oilseed exports, the world trade in soybeans being dominated by the United States.

Although there are no projections available for future world trade in pulses, Table XIV indicates the demand forecasts for pulses and nuts to 1980. It is projected that world demand for pulses and nuts will climb by over 50% between 1965 and 1980. In the EEC countries, where pulse production has been declining over the years, future demand is forecast to increase.

Demand projections between 1970 and 1980 for edible oils and fats indicate an annual increase in total world demand of 2.7% with consumption increasing from 41 to 53 million metric tons. The less developed countries are expected to record the fastest rate of increase in total demand, growing by 4% per year. If the demand can be satisfied, it is predicted that developing countries will consume one-third of the world's oils and fats by 1980. In 1965, the less developed nations consumed barely 25% of world production. The more developed countries are forecast to increase their consumption of oils and fats at a rate of 1.6% per year.

Population and Demand

The increased world oilseeds demand will have a strong effect on world trade. Between 1970 and 1980, the volume of oilseeds and fats and oils exported is expected to rise from 4.6 to 13.9 million metric tons, a 4.1% annual increase. The increased demand for oilseeds and legumes is the result of several factors, not the least being world population growth. By 1980 there will be about 850 million more mouths to feed than there were in 1970.

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The sheer increase in the number of humans will exert a powerful force on world markets and require production of the means to feed 23% more people in 1980 than in 1970. Increasing incomes among certain sectors of the world's population will probably lead to a demand for more legumes, especially among those people with improved, but still low, incomes who wish to change their consumption patterns by eating more plant proteins. For many others in the world, rising incomes will lead to an increased demand for animal proteins placing added pressure on agricultural producers to satisfy this demand through the production of more meat products, and the plant proteins needed to feed the animals required. Indeed, while per capita world income is projected to increase by 36% between 1970 and 1980, incomes in the more developed nations will probably rise by 50% with Japan's per capita income growing by 131%. As disposable personal income rises, it is customary for the consumption of animal products to rise accordingly.

Protein Supplements for Animal Feeds

The future of the world livestock and animal protein industry is thus an important determinant of the manner in which the production of pulses and protein supplements in general will develop, since animal feeds consist largely of cereals supplemented with legume or other protein sources. World meat consumption, excluding poultry, doubled during the period 1948-52 to 1970. World demand for beef and veal, mutton and lamb, pig meat and poultry meat and their products is projected to increase by an average of 3.1% per year from 1970 to 1980. Since it will be difficult for animal production to match demand, the inflationary trends in grain and legume prices is not expected to recede over the foreseeable future. In the more developed countries, consumption will rise by 28% between 1970 and 1980 while in the less developed countries the estimated growth of meat consumption between 1970 and 1980 is 50%. In the centrally planned economies the demand for meat may rise by 40%. These comparatively rapid rates of growth will naturally have a strong effect on the market for protein supplements. As the demand for meat increases, a proportionately greater increase in the demand for plant proteins occurs, since the conversion efficiency of plant protein into animal protein is relatively low. If world demand for meat and animal products grows by a steady 3% per year during the 1970s, the demand for high protein feed supplements may well rise by 5 or 6% per annum.

During 1971-72, Europe produced only 4.3% of its total supplies of animal feed protein. The demand for high quality protein has accelerated with the trend to the utilization of mixed feeds. From 1960 to 1972, the use of vegetable protein has increased annually by 10.5%, with imports to the EEC countries jumping by 47% between 1966 and 1972. Thus, Europe promises to continue to be a major importer of pulses and oilseeds during the next decade. In Japan, total meat consumption is expected to grow by 7.4% annually to 1985 when the demand for meat will be three times what it was in 1970.

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Bearing in mind the total world demand for edible protein and the high cost in comparative inefficiency of providing this protein from animal sources, much more attention must be given to increasing the availability and acceptability of edible protein from plant sources, particularly from combinations of cereals and food legumes.

Factors Which Influence Legume Supply

The availability or supply of legumes is determined by a complex of variables which differ for the various producing regions of the world. Initially, one must distinguish between farmers participating in the cash economy and subsistence farmers who will grow enough to provide for the needs of their family, but will not grow the crops to be marketed and perhaps eventually exported. For the cash farmers, the overriding consideration is profitability, and for buyers of legumes, it is whether the crop is competitively priced. For the farmer to sell his produce competitively and still receive an adequate return for his investment, he must obtain good crop yields.

In the present world situation, prices are quite high and judging from the future demand to be expected for legumes, unless there is a sudden increase in legume production, prices will remain relatively high. It is thus the economics of growing the crop and the yield potential of legumes which is of most concern to the farmer and, ultimately the consumer. Although the legume crops require similar treatments for weeds and insects as do other crops, they can be grown on stubble and because of their nitrogen-fixing capability do not require high applications of fertilizer which other crops require. In addition, some of these crops can be harvested with conventional cereal equipment, allowing further savings for the farmer.

With regard to yields, actual farm yields for legume crops, such as faba beans, being grown by Canadian farmers, have reached up to 3,500 pounds per acre. Test plot results have ranged from 2,000 pounds to over 7,000 pounds per acre. At the University of Manitoba, average crop yields in pounds per acre over a two-year period equalled or came close to Glenlea wheat, and exceeded Glenlea in the protein produced per acre. Legume crops would therefore appear to have a great yield potential which only remains to be exploited.

For many farmers, the monetary risk in growing legumes is their primary concern. Notwithstanding what was stated above, and as is shown in Table XI, yields of legumes and oilseeds are low compared with cereals. Many legumes are highly susceptible to infestation and infection. Consequently, a more concentrated program of research to improve legume production is urgently needed. With this in mind, IDRC is supporting legume improvement programs in Asia, Africa, the Caribbean and the Near East.

It appears certain, particularly in developed countries, that legumes will be much more extensively used in compounded animal feeds. Livestock producers can also grow legumes on their farms, thus avoiding the necessity of paying for protein supplements, consequently reducing their cash flow.

Legumes are also being progressively used in a variety of new human food products particularly as meat substitutes or meat analogues as they are sometimes called. As this market develops, there will be a greater industrial demand for legumes. With the unlimited domestic and export opportunities now available for legumes and with the many markets developing which will require legumes as a major ingredient in their products, the element of monetary risk involved in growing these crops is likely to be less in the future than in the past.

Research to Improve Legumes

In developing countries, on-farm yields of legumes are often less than 0.5 tons per hectare, as opposed to the world average of maize at 2.8 tons per hectare. Given the fact of the comparatively low yields of legumes as opposed to cereals, many farmers, Asian farmers in particular, have preferred to increase the area planted with cereals at the expense of legumes. At present, at the international agricultural research centres, the most superior varieties of wheats yield close to 8 metric tons per hectare whereas the best legumes yield only 3.6 tons per hectare. To a significant extent the disparity in yields between cereals and legumes is a reflection of the relative amount of money and effort invested in research into these crops. Nevertheless, early results from the program which IDRC is supporting at the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT) in India indicate that research will give rise to legumes of superior yielding capability and nutritional quality.

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In addition to genetic selection to improve pulse yields, agronomic research has also contributed to increased yields. At the International Institute of Tropical Agriculture (IITA) in Nigeria, agronomic research on several facets of legume cultivation has led to significant yield improvements. A 40% yield increase resulted from a change in tillage practice. Spacing, population density, weeding, harvesting and date of planting experiments all indicated systems by which to increase yields. For instance, two to four-fold yield improvements were realized by harvesting every week instead of every three to six weeks.

Furthermore, increased overall productivity can be obtained through improved cropping systems particularly multiple cropping systems. Multiple cropping includes intercropping in which two or more different crops are grown simultaneously, or sequence cropping in which one is planted before the other is harvested, or rotational cropping in which, for example, a cereal crop and a legume crop are grown one following the other.

Research conducted in Tanzania using cereal-soya intercropping combinations has produced yields over 30% greater than monoculture plots. At the International Rice Research Institute (IRRI) in the Philippines, land productivity using intercropping was increased by 30 to 60% over monoculture in experiments with soybeans, groundnuts, mung bean and other legumes, in combination with rice and maize.

Since legumes are essentially a protein source, more attention needs to be given to quality grading and in particular to adopting grading standards which relate price to protein content. Appropriate international and national standards which encourage the production of high quality legumes would provide an incentive to farmers by giving them a higher price for a nutritionally superior product. Such incentives exist in North America for cereal grains, such as wheat, and for other protein sources sold to animal feed industries which buy largely on the basis of protein content.

Processing of Legumes

Legumes suffer almost universally from the stigma of being regarded as the food of the poor. The Ancient Romans described beans as "a poor man's meat", and even today in Latin America, a poor man is one who is described as counting his garbanzos (chick-pea). Legumes can be made more attractive and their monetary value increased through improved processing technology. In North America and Europe, high protein breads demand a premium price over conventional bread. On a cost per calorie or a cost per gram of protein basis, protein-enriched breakfast cereals and snack foods are significantly more expensive than bread or other traditional cereals. The cost per gram of protein in a protein-enriched breakfast cereal is presently about 1.4¢ per gram whereas the cost in ordinary bread is 0.6¢ per gram of protein. High protein infant foods are generally more expensive than the sum of the ingredients which go into their manufacture.

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Consequently, particularly in poor developing countries, a great opportunity exists for the production of infant and weaning foods from locally produced cereals and legumes to replace expensive imported products.

The market for meat analogs and other uses of high protein products offers good prospects for future expansion. A number of vegetable products are now available, some comparatively inexpensive, which closely resemble carcass meats and may be used as total or partial replacements. In the United States in 1969, 270,000 metric tons of soyflour and grits, 16,000 metric tons of concentrates, 11,000 metric tons of isolates and 14,000 metric tons of textured soy protein foods were produced, representing 0.7% of total U.S. red meat consumption. In Japan in 1971, approximately 27,700 metric tons of meat substitutes were manufactured and in the USSR during the same period, 10,000 metric tons were produced. The demand for legumes in pet foods has also increased, with a potential market of 200,000 metric tons foreseen for 1980.

It is envisaged that by 1980, 2.6 million metric tons of meat substitutes and extenders, representing a 3% substitution, will replace natural meat.

New methods of milling legumes to produce legume flours are also being developed, such as one at the Prairie Regional Laboratory in Saskatoon in cooperation with a cereal and legume mill in Northern Nigeria.

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The process consists of the simple abrasive decortication of the legume using rotary carborundum disks. The decorticated cotyledons are ground to a flour of predetermined particle size by hammer mills or mosaic grinders. This technology permits the simple and inexpensive manufacture of foods for infants, young children, nursing mothers and other nutritional evaluation groups in which the optimum ratio of cereal and legume protein is ensured.

Composite Flours

In Britain and Canada new techniques for making bread by what is known as mechanical development permits good quality bread to be made from mixtures of 50% of wheat flour with 50% mixtures of other cereals, such as sorghum, maize and millet, and legumes flours such as cowpea, chick-pea or soybean.

The consumption of bread from imported wheat has increased dramatically in many developing countries over the past decade. For example bread consumption in Africa is increasing at roughly 8% per year. More than 37% of the small and medium sized bakeries in India came into existence during the second half of the 1960s. During the same 5-year period, wheat and wheat flour imports increased by 42% in Africa, by 23% in Asia, by 44% in Central America and the Caribbean, and by 35% in South America.

"Composite flours" is the name given to combinations of wheat flour with other cereal flours such as maize, sorghum and millets, supplemented with legume flours. As indicated above, techniques by which to produce acceptable bread containing only 50% wheat flour are now available. The cereal and legume flours can be

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produced by a simple mill, such as the one existing at Maiduguri in Northern Nigeria, and the breadmaking process requires comparatively simple equipment including a pair of sheeting rollers which can be operated by hand or mechanical motor.

The subject of composite flour technology has been described by J.H. Hulse in "New Protein Foods" (edited by A. Altschul, Academic Press 1974) and in "The Nutritional Value of Triticale Protein" by J.H. Hulse and E.M. Laing (IDRC 1974).

Composite flours may also be used to produce high protein cereal foods, including bread, biscuits, alimentary pastes (noodles, macaroni, etc.), infant and weaning foods.

Cereal and Legume Protein Concentration

Protein concentration of cereals has been performed using fine grinding and air classification for many years, using the principle that in a finely ground flour the carbohydrate is massed in the heavier particles. By applying a centrifugal force, opposed by a centripetal air drag to the fine flour particles, the heavier particles move in one direction, and the finer protein-rich particles in the other direction. In theory, air classification is easier to achieve with legume flours than with cereal flours since legume flours contain, in general, much larger starch granules. At the Prairie Regional Laboratories this has been verified, where field pea flour has been converted to significantly higher protein contents. This technology is not as inexpensive as simple milling, but it is simpler, less expensive, and less hazardous in tropical countries to operate than the "wet" system of producing protein concentrates. Iso-electric washing is a third method of protein extraction used to produce protein concentrateswith a 60-70% protein content. It involves the aqueous extraction of the protein at its iso-electric point which thus precipitates the protein. Aqueous or alkaline extraction and acid precipitation are used to produce protein isolates containing about 90% protein.

Textured protein foods have also been produced based on edible, spun soy protein filaments. Following aqueous extraction of the protein material, the protein is precipitated and subjected to other treatments which produce a slurried 95% pure protein. The slurry is then extruded through spinnerets, followed by stretching and heat treatment to produce a ribbon or two of monofilaments. Ingredients are added to the tow and various high protein products are then formed. Though most research and development on textured vegetable proteins has been applied to soybeans, there is little doubt that meat substitutes and other textured products can be made of proteins concentrated from other legumes.

Future Demand for Plant Proteins

The demand for protein products on world markets at present is readily apparent, and the future demand as portrayed above, has been forecast to increase with the possibility of shortages developing by 1980. Legumes and oilseeds can help

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to meet these demands and an increase in their production must be encouraged. This can be achieved in part by stimulating new research and continuing the support for ongoing research to improve the yields, protein content and resistance to disease and infestation of the principle legume and oilseed crops. Research must also be directed to the improvement of the productivity of cropping systems involving both cereals and legumes such as maize and beans, sorghum and safflower, millet and cowpeas, and rice with soy or mung beans. Research must be conducted to convert legumes by simple processing to forms which are more nutritious, attractive and inexpensive for consumers, particularly in developing countries. Every effort must be made to ensure that the malnourished who desperately require these foods do indeed receive them. For those underfed millions in the world who are not subsistence farmers and therefore cannot consume crops they have grown themselves, the distribution of low-cost protein and calorie foods must be made more widespread.

Finally, more effective methods of tendering advice and information to government policy makers on the importance of legumes and oilseeds must be developed. The information and advice should clearly indicate to the policy makers what actions are possible and desirable to increase legume and oilseed production

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and to make legumes and oilseeds more attractive commodities for farmers to cultivate, various processors to utilize in food and feed products, and for consumers to purchase.

TABLE I

Calories and protein supplied by cereal grains, food legumes and nuts in diets in the developing countries (Percent of total calories and proteins)

	Calories	Protein
Africa	58.5	61.3
Asia and Far East	72.1	77.3
Latin America	47.0	54.8
Near East	67.0	72.0
All Developing Countries ..	65.1	70.3

Source: (FAO. Food Balance Sheets 1964-66 Average. Rome: FAO, 1971.

TABLE II

Possible protein supplements for cereal foods and feeds

Synthetic Amino Acids	Animal Proteins	Fish Proteins
Lysine	Egg	Fish meal (Dried and defatted fish)
Methionine	Milk	Fish Protein Concentrate (Solvent extracted fish flesh or whole fish: ca 90% protein)
	Whey	
	Animal Blood	
	Meat By-Products	
	Bird Feathers	
	Processed Wool	

Plant Proteins	Microbial Proteins	
Legume flours	Yeasts	)Substrates include carbo-
Oilseed flours	Algae	)hydrates, hydrocarbons)(natural gas, petroleum wax,
Cereal germ	Micro fungi	)etc.), industrial and agri-
Cereal bran	Bacteria	)cultural wastes and by-products)
*Cereal protein concentrate		
*Legume protein concentrate		
Leaf and grass concentrates		
Coffee pulp concentrates		

*By particle size separation, aqueous or solvent extraction

TABLE IIIa

Amino acid content of wheat plus chick-pea
(mg/gN)

	WHEAT	CHICK-PEA	WHEAT (67%) CHICK-PEA (33%)	AA SCORE	WHO RECOMMENDED AA COMPOSITION
LYSINE	179	428	304	89	340
THREONINE	185	235	209	85	250
METHIONINE & CYSTINE	253	139	196	89	220
LEUCINE	417	468	443	100	440
ISOLEUCINE	204	277	241	96	250
VALINE	276	284	280	90	310
PHENYLALANINE & TYROSINE	469	541	505	133	380
TRYPTOPHAN	68	50	59	100	60

TABLE IIIb

Amino acid content of rice plus chick-pea

(mg/gN)

	RICE	CHICK-PEA	RICE (75) CHICK-PEA (25)	AA SCORE	WHO RECOMMENDED AA COMPOSITION
LYSINE	237	428	333	98	340
THREONINE	244	235	240	96	250
METHIONINE & CYSTINE	212	139	176	80	220
LEUCINE	514	468	491	112	440
ISOLEUCINE	238	277	258	103	250
VALINE	344	284	314	101	310
PHENYLALANINE & TYROSINE	540	541	540	142	380
TRYPTOPHAN	102	50	76	126	60

TABLE IV

Protein consumption per capita by major food groups

	Cereals	Starchy Roots	Pulses & Nuts	Vegetables & Fruit	Meat, Eggs Fish & Milk	Total
			Grams Per Day			
North America	15.9	2.4	4.1	4.9	70.7	98.2
Central America	31.6	0.5	11.9	2.0	22.8	58.0
Caribbean	21.4	3.3	8.3	2.2	22.8	58.0
Africa	33.3	5.2	8.5	1.9	12.1	61.0
Near East	45.1	0.6	4.7	3.3	12.2	65.9
South Asia	32.3	0.5	8.6	0.6	6.3	48.3
China	31.8	2.9	10.8	2.2	8.8	56.5

TABLE V

Available supplies in energy and protein in 1970
expressed as a percentage of per capita nutritional requirements

	Daily Per Capita Requirements		Available Supplies as % of Requirements 1970	
	Calories	Protein	Calories	Protein
World	2,385	38.7	100	173
Developed Countries	2,560	39.5	121	229
Developing Countries	2,284	38.4	96	147
Asia and East Asia	2,223	36.6	93	141
Latin America	2,383	37.7	106	172
Africa	2,335	41.5	93	141
Near East	2,456	45.5	97	147
Asian Centrally Planned Economies	2,355	38.3	88	153

TABLE VI

World production of major legumes, 1972

Botanical Name	Common Name	World Production (1000 metric tons)	% World Legume Production
Glycine max	soybean	53,024	49.4
Arachis hypogaea	groundnut peanut	16,887	15.7
Phaseolus vulgaris	kidney bean pea beans navy bean haricot bean pinto bean snap bean common bean black bean	10,899	10.2
Pisum sativum	green pea garden pea pea	10,218	9.5
Cicer arietinum	chick-pea Bengal gram gram	6,718	6.3
Vicia faba	broad bean horse bean Windsor bean faba bean	5,326	5.0
Cajanus cajan	pigeon pea red gram congo bean	1,720	1.6
Vigna unguicalata (vigna sinensis)	cowpea blackeye pea catjan pea Hindu cowpea Kaffer bean	1,260	1.2
Lens esculenta	lentil split pea red dhal	1,182	1.1
	WORLD TOTAL	107,234	100.

TABEL VII

Percentage change in world population and pulse production, 1952-1972.

	Population (%)	Total Food (%)	Food Per Capita (%)	Pulses (%)
Developed	22	60	32	87
Latin America	62	65	2	100
Near East	57	65	2	48
Asia and Far East	51	65	9	21
Africa	52	47	-3	55
All Developing	53	62	6	40
World	40	61	15	49

Source: (FAO 1971b and FAO 1973b).

TABLE VIII

World area, production and yield of certain crops, 1972.

	World Area (1,000,000 ha.)	World Production (1,000,000 metric tons)	World Yield (kg/ha)
Cereal Grains			
Wheat	213.5	347.6	1628
Rice	131.2	295.4	2251
Barley	849.2	152.2	1793
Maize	108.2	301.4	2785
Millet	65.1	43.0	660
All Cereals	698.4	1,275.1	1826
Pulses			
Beans	22.3	10.9	489
Peas	9.3	10.2	1103
Broad Beans	4.7	5.3	1137
Chick-peas	10.5	6.7	637
Lentils	1.7	1.2	689
Pigeon peas	2.6	1.7	665
Cowpeas	5.0	1.3	254
Vetch	1.9	2.0	1087
Lupins	1.0	0.8	721
Other Pulses	6.3	3.6	564
All Pulses	65.3	43.7	669
Oilseeds			
Soybeans	38.5	53.0	1378
Groundnuts	19.7	16.9	859
All Oilseeds	124.0	128.9	1040
TOTAL	887.7	1,447.7	1631

Source: (FAO 1973b).

TABLE IX

Comparative annual average rate of growth in production, selected crops, 1961-63 to 1969-71

	(PERCENT)						
	Total Agricultural Production '61-63 to '73	Population Growth '62-'72	Wheat	Rice	Total Grains	Starchy Roots	Pulses
			1961-63 to 1969-71				
Africa South of the Sahara	2.7	2.4	5.1	4.4	2.5	2.7	1.9
Far East	2.9	2.5	7.5	2.5	3.1	5.5	– 0.7
Near East and Northwest Africa	3.2	2.9	2.0	4.5	2.4	2.9	3.0
Latin America	2.9	2.8	1.3	3.4	3.3	4.7	3.0
TOTAL	2.9	2.7	4.4	2.7	3.0	3.9	0.7

Source: (FAO 1973d, UN 1974).

TABLE X

World area and production of pulses

	Area (1,000 ha.)		Production (1,000 mt.)	
	1948-52	1968-72	1948-52	1968-72
Dry Beans	15,337	22,850	6,778	11,058
Dry Peas	6,829	9,100	5,824	10,393
Broad Beans	4,567	4,703	4,390	5,138
Chick-Peas	10,200	10,231	5,370	6,728
Lentils	1,581	1,685	845	1,078
Pigeon Peas	2,432	2,831	1,412	1,900
Cowpeas	1,557	4,113	540	1,146

TABLE XI

Pulses and oilseed production and yields 1952 and 1972

	Production (1,000,000 mt)		Yield (kg/ha)	
	1948-1952	1968-1972	1948-1952	1968-1972
Pulses	29	44	570	670
Oilseeds	58	129	625	987
Maize	140	278	1590	2582
Wheat	171	333	990	1531

TABLE XII

Price fluctuations of the principal legume crops and oilseeds in international trade 1972, 1973, 1974

(for long tons 2,240 lb., in US dollars)

	1972		1973		1974		1975	
	January	Jul/Aug	January	Jul/Aug	January	Jul/Aug	January	Jul/Aug
Beans	336.60	269.50	270.25	465.50	1173.00	1071.00	432.90	386.26
Peas	149.18	183.75	219.73	392.00	816.50	583.10	468.00	342.20
Broad Beans	103.00	85.75	103.40	196.00	149.50	154.70	150.93	121.52
Lentils*	178.50	176.40	197.40	428.75	425.50	483.14	456.3	466.55
Soybeans	132.86	140.63	270.75	--	276.35	259.00	300.50	224.50
Groundnuts	251.18	267.05	324.30	--	529.00	--	655.20	272.34
Rapeseed	126.48	135.24	177.43	--	419.75	--	458.06	--
Cottonseed	97.00	--	106.00	--	225.00	235.00	260.00	175.00
Sesame*	330.00	327.00	310.00	--	480.00	585.00	635.00	650.00

* metric tons

TABLE XIII

Volume and value of pulse exports and imports, and as a percentage of production, 1972

	EXPORTS 1972 (1,000mt)	($m)	IMPORTS 1972 (1,000mt)	($m)	Exports as % of Produc.	Imports as % of Produc.
World	1,893	349	1,987	401	4	5
Developed	662	129	1,334	268	18	36
N. America	307	63	29	9	27	26
W. Europe	311	59	1,071	213	15	52
Oceania	37	5	16	5	47	20
Other	6	2	217	42	15	54
Developing	960	172	594	123	4	3
Africa	428	61	77	17	9	2
Latin America	168	40	223	55	4	5
Near East	132	29	106	19	8	6
Far East	232	41	183	31	2	1
Central Planned	271	48	59	10	2	0
Asia	119	18	25	3	1	0
USSR & Europe	152	30	34	7	2	0

TABLE XIV

Demand projections, pulses and nuts

	Level of total demand (1000 metric tons) 1965	1975	1980	% increase 1965-1980
World	34,641	45,340	52,615	52
Economic Class I	3,803	4,285	4,510	19
North America	857	863	914	7
Western Europe	2,397	2,733	2,877	20
EEC	1,143	1,251	1,320	15
Oceania	41	52	60	46
Other Developed	543	626	687	27
Economic Class II	23,773	32,440	38,049	60
Africa	3,332	4,486	5,276	58
Latin America	4,478	6,042	7,035	57
Near East	1,069	1,562	1,892	77
Asia and Far East	14,744	20,207	23,812	62
Economic Class III	7,107	8,855	9,954	40
Asian Centrally Planned Economies	5,490	7,032	7,880	44
USSR - Eastern Europe	1,563	1,826	1,999	28